

## **Reliability Evaluation of Base-Metal-Electrode (BME) Multilayer Ceramic Capacitors for Space Applications**

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This paper reports reliability evaluation of BME ceramic capacitors for possible high reliability space-level applications. The study is focused on the construction and microstructure of BME capacitors and their impacts on the capacitor life reliability.

First, the examinations of the construction and microstructure of commercial-off-the-shelf (COTS) BME capacitors show great variance in dielectric layer thickness, even among BME capacitors with the same rated voltage. Compared to PME (precious-metal-electrode) capacitors, BME capacitors exhibit a denser and more uniform microstructure, with an average grain size between 0.3~0.5  $\mu\text{m}$ , which is much less than that of most PME capacitors. The primary reasons that a BME capacitor can be fabricated with more internal electrode layers and less dielectric layer thickness is that it has a fine-grained microstructure and does not shrink much during ceramic sintering. This results in the BME capacitors a very high volumetric efficiency.

The reliability of BME and PME capacitors was investigated using highly accelerated life testing (HALT) and regular life testing as per MIL-PRF-123. Most BME capacitors were found to fail with an early dielectric wearout, followed by a rapid wearout failure mode during the HALT test. When most of the early wearout failures were removed, BME capacitors exhibited a minimum mean time-to-failure of more than  $10^5$  years.

Dielectric thickness was found to be a critical parameter for the reliability of BME capacitors. The number of stacked grains in a dielectric layer appears to play a significant role in determining BME capacitor reliability. Although dielectric layer thickness varies for a given rated voltage in BME capacitors, the number of stacked grains is relatively consistent, typically between 10 and 20. This may suggest that the number of grains per dielectric layer is more critical than the thickness itself for determining the rated voltage and the life expectancy of the BME capacitor. Since BME capacitors have a much smaller grain size than PME capacitors, it is reasonable to predict that BME capacitors with thinner dielectric layers may have an equivalent life expectancy to that of PME capacitors with thicker dielectric layers.